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EXECUTIVE SUMMARY

The use of prescribed fire as a management tool is becoming increasingly more prevalent as land managers embrace the objectives of ecosystem management and restoration ecology. To date, there has been much research done on a wide range of issues concerning prescribed fire; from physiological and ecological aspects at one end of the spectrum to social and economic concerns at the other. Although the majority of the literature addresses the physical aspects of fire, economic and social considerations are equally important.

Prescribed burning can be analyzed from a wide variety of economic perspectives and can provide the foundation from which to compare costs and benefits and estimate management efficiency. For example, it can be used to evaluate the efficacy of prescribed fire applications, and to assess the reduction of risk and hazard associated with reduced fuel loading. Moreover, economics may provide the basis for the formulation of federal policy. The extent to which economic theory is used to make decisions and formulate Forest Service policy is the focus of this bibliography.

This document summarizes current Forest Service research programs and existing literature with respect to the economics of prescribed fire. Although the primary emphasis is placed on the economic aspects of Rx fire, the bibliography includes literature pertaining to physical and ecological research that may enhance economic understanding of production processes. The document is divided into four sections; recommendations, annotated bibliography, Forest Service research and a full citation of all articles in the database. The annotated bibliography is organized according to the following topics:

- Policy and planning,
- Economic efficiency, cost and damage,
- Risk and uncertainty,
- Urban-interface and risk,
- Hazard, fuels management and modeling,
- Decision making and computer analysis,
- Forest health and ecosystem management.

RECOMMENDATIONS

After completion of an extensive literature review, it is clear that economic research with respect to prescribed burning is relatively scant. Similarly, Forest Service policy regarding prescribed fire is not entirely economically based. Overall, there is a lack of research investigating the success of prescribed fire programs in meeting fire management objectives as well as the related cost effectiveness of such programs both in the short and long run.

Prescribed fire is employed for a variety of reasons including reduction of risk and damage, the enhancement of ecosystem management and health objectives, and as a tool to mitigate both the damaging effects of wildfire and increasing suppression costs. The question is, does the use of prescribed fire meet these objectives? If so, is prescribed fire a cost effective management tool? The answers to these questions are not apparent in the literature. To assess the economic effects of prescribed burning, it would be useful to investigate these issues and to establish an economic methodology by which to formulate policy and evaluate the application of prescribed fire.

Three general recommendations for research and inquiry into the economic aspects of prescribed burning are outlined below.

- Economic implications of prescribed fire policy should be considered in terms of *long- and short-run management objectives.* Develop an economic framework within which to assess the negative and positive aspects of prescribed fire and to evaluate the long term costs and benefits in achieving overall fire management objectives.

- Although prescribed fire is often used to reduce hazard and related damage associated with high and increasing fuel loads, the long-term effects are unknown. Establish a long-term study to evaluate the effectiveness of prescribed fire programs in systematically reducing *physical and financial damage.*

- Prescribed burning may be considered prohibitively costly in the short-term, and therefore not implemented in favor of less costly alternatives. Although the literature pertaining to the costs of prescribed burning is relatively abundant, what is required is an analysis of the role of prescribed burning in improving the *long term cost effectiveness* of the total cost of fire management including suppression.

Understanding the economic effects of Forest Service policy and program alternatives will enable managers to make decisions to better meet fire management objectives including long-term cost minimization, management efficiency damage reduction.

ANNOTATED BIBLIOGRAPHY

POLICY AND PLANNING

The Forest Service wildland fire policy has recently been reviewed and recommendations have been make to include a more integrated approach to fire management and planning. The most recent policy recommendations are summarized in the two USDI/USDA documents listed below. Policy recommendations regarding the use of prescribed fire, as listed in the action report, are as follows:

11. Jointly develop programs to plan, fund and implement an expanded program of prescribed fire in fire-dependent ecosystems.
12. Facilitate the planning and implementation of landscape-scale prescribed burns across agency boundaries.
13. Require appropriate treatment of fuel hazards created by resource-management and land-use activities.
14. Conduct all prescribed fire projects consistent with land and resource management plans, public health considerations, and approved prescribed burn plans.
15. Implement the National Wildfire Coordinating Group (NWCG) interagency prescribed fire qualification and certification standards.
16. Train and maintain a qualified and adequate work force to plan and implement interagency prescribed fire projects safely and effectively, and make these personnel available when needed.
17. Jointly develop simple, consistent hiring and contracting procedures for prescribed fire activities,
18. Conduct research and development on fuel treatment alternatives and techniques.
19. Seek authority to eliminate internal barriers to the transfer and use of funds for prescribed fire on non-Federal lands and among Federal agencies.
20. See authority or provide administrative direction to eliminate barriers to carrying over from one year to the next all funds designated for prescribed fire.
21. Work with the Office of Personnel Management to acquire authority for hazard pay to compensate employees exposed to hazards while engaged in prescribed burning activities.
22. Clarify that prescribed fire positions qualify for primary coverage under special firefighter retirement, and issue appropriate guidance to field offices.
23. Jointly develop an assessment process for determining the probability of success and/or failure associated with the use of prescribed fire and evaluation potential positive and negative consequences. As a part of this process, the effects of not conducting the project will also be evaluated.
24. Jointly develop tools to identify, assess, and mitigate risks from prescribed fires.
25. Create an organizational climate that supports employees who implement a properly planned prescribed fire program.
26. Reevaluate prescribed burn planning and execution requirements to ensure adequacy of direction without unnecessary constraint. The Secretaries of the Interior and Agriculture will seek legislation providing for prompt reimbursement to private landowners for damages resulting from escaped prescribed fires originating on Federal lands.

Although many of the action items listed above are indirectly related to economic and social outcomes, none address economic objectives directly. The policy recommendations are relatively broad and reflect a combination of social and environmental objectives. It is therefore difficult to isolate a comprehensive set of economic objectives and theories upon which Forest Service policy, with respect to prescribed burning, is based.

Current Forest Service Policy

Strategic:

USDI/USDA (1996). Federal Wildland Fire Management Policy and Program Review Implementation Action Plan Report. Washington, D.C., USDI/USDA.

> *The Federal Wildland Fire Policy Review (Policy Review) directly affects only Department of Agriculture and Interior agencies. However, it significantly, although indirectly, affects local,*

State, and Tribal governments as well as other federal partners. The Federal Fire and Aviation Leadership Council (Leadership Council) established an Action Plan Development Team, which provided a report of the requirements outlines in the Implementation Strategy. The Leadership Council conducted independent reviews of the Action Plan Development Team's report to refine recommendations based on review by internal staff, the Federal Fire and Aviation Leadership Council, and Federal Geographical Area Coordinating Group representatives. These reviews culminated in a finalized draft Action Plan Report. Eighty-three Action items are summarized in the report under the following headings:

- Role of Fire in Resource Management,
- Use of Wildland Fire,
- Preparedness and Suppression,
- Wildland/Urban Interface Protection,
- Coordinated Program Management,

USDI/USDA (1995). Federal Wildland Fire Management Policy and Program review report. Washington, D.C., USDI/USDA.

This document is provides the basis for the 1996 Action Plan Report. *Principles, policies and recommendations provide a common approach to wildland fire by the two departments and implications for federal partner agencies including the federal Emergency Management Agency, the Environmental Protection Agency, the National Oceanic and Atmospheric Administration, and the Department of Defense, such that the approach to wildland fire is truly federal. The principles and policies of the report support the priority of protecting people first, and resources and property second, based on relative values to be protected.*

Tactical:

Anonymous (1988). Fuel Management Planning and Treatment Guide. Missoula, MT, USDA Forest Service, Northern Region.

This guide is the result of a major revision of the Northern Region's Fuel Management Planning and Treatment Guides originally prepared in the late 1970s and is the most current document used for the application of prescribed fire. This updated version represents a complete restructuring of the guide in an attempt to assist the field practitioner in accomplishing the fuels management job. The guide begins with management direction including forest plan coordination, program planning process and fuel treatment references. The second section pertains to project identification: fuel management and forest plan implementation, appraisal of fuels and fire potential, and fire effects. Third, treatment methods including: pretreatment conditions and, fuel treatment options.

Planning

The Forest Service is increasingly embracing the importance of prescribed burning to meet ecosystem management and cost efficiency objectives. The following articles make recommendations and suggest guidelines for effectively incorporating prescribed burning into management plans.

Anonymous (1996). Land management considerations in fire-adapted ecosystems: conceptual guidelines. Washington, D.C., USDA Forest Service, Fire and Aviation Management.

This guide is intended to establish a conceptual framework for integrating fire management considerations into the planning process for fire dependent ecosystems. With respect to prescribed fire, risk, smoke management, ecosystem objectives and ecosystem health are considered.

Anonymous (1995). Course to the future: positioning fire and aviation management. Washington, DC, Fire and Aviation Management, USDA Forest Service.

This report draws on a wide group of recently completed Forest Service reviews, summaries, and assessments. Its findings also reflect a gamut of issues and concerns that have appeared repeatedly since 1985. The historical trend data, along with program results, indicate a serious need to change or adjust Forest Service program emphasis. The enclosed recommendations, therefore, target a new direction and strategy in fire management. Five key recommendations are

listed with respect to the following topics: ecological processes, sustaining fire-dependent ecosystems, forest land management planning, wildland/urban interface, and reorienting the workforce.

Bell, E., David Cleaves, Harry Croft, Susan Husari, Ervin Schuster, and Dennis Truesdale. (1995). Fire Economics Assessment Report, USDA Forest Service.

The rising cost of fire suppression activities prompted the Regional Fire Directors, under the leadership of the Director of Fire and Aviation Management, to review the causes of these increased costs and recommend appropriate actions. The Fire Economics Assessment report is one of a series of reviews and reports following the 1994 fire season. The team found that the real expenditures for fire suppression have not increased since 1970 if 1994 expenditures are excluded, and that real expenditures for presuppression activities and fuel treatments have declined over the past 25 years. This report summarizes the team's deliberations and identifies a number of opportunities to reduce costs. It also identifies how current policy and direction will only increase costs, not reduce them.

Williams, J. T., R.G. Schmidt, R.A. Norum, P.N. Omi, and R.G. Lee (1993). Fire related considerations and strategies in support of ecosystem management., USDA Forest Service, Washington Office.

Fire plays an essential role in sustaining these ecosystems but has not been recognized as a fundamental ecological disturbance process when developing management policies and practices. Sustaining fire-adapted ecosystems is emerging as an important agency challenge. However, given the complex, contentious issues that surround fire use there is continuing uncertainty over the role of fire and our ability of sustain these ecosystems. Paradoxically, although there is some growing recognition of fire's role in these ecosystems, there is a diminishing social tolerance for smoke and other adverse effects that accompany burning. Also, there are fewer dollars available to finance the cost of treatment. The consequences of excluding periodic low-intensity fire in these ecosystems are not without serious risk, as forest health problems throughout the west bear out. Air quality standards, risk avoidance, and competition between functional interests often preclude the use of prescribed fire. But, no matter how well intentioned, these reasons may overlook the larger issue of ecosystem health. Larger scale prescribed burning in short interval fire-adapted ecosystems is biologically appropriate and consistent with Ecosystem Management principles. Sustainability - a satisfactory social, economic, and biological solution - will remain elusive until there is a better conceptual understanding of the long-term risks and consequences of fire control and fire use alternatives in these systems.

Prescribed Fire Policy

The following two articles explore policy issues and examine the role of prescribed fire as a management tool.

Koehler, J. T. (1992-1993). "Prescribed burning: a wildfire prevention tool?" Fire Management Notes 53-54(4): 9-13.

A number of fire managers recommend prescribed burning as a tool to prevent wildfire. However, there is little data to support this recommendation, and additional research has been needed to answer the following questions: does prescribed burning reduce the size and intensity of wildfire? Are the effects of prescribed burning as a wildfire prevention tool measurable? Does prescribed burning eliminate the threat of wildfire? The author explores answers to these questions by looking at fire statistics of the Florida Division of Forestry, Orlando District from 1981 to 1990.

Omi, P. N. (1989). "Policy directions: Lessons from fires of 1988." Forum for Applied Research and Public Policy 42(2): 41-45.

The author explores the controversy and policy implications resulting from the 1988 fires. He discusses fire management including natural fire policy where fires are allowed to burn in selected backcountry areas as well as other policy problems and economic issues. He advocates refinement and re-evaluation of existing fire management plans, particularly the need to repudiate noninterference as a viable ecosystem management strategy. Rather, he suggests that the greatest

payoff lies in proactive intervention, primarily fuel hazard abatement in high-risk areas, using prescribed fire or other techniques, in anticipation of wildfire outbreaks.

ECONOMIC EFFICIENCY, COST, and DAMAGE

The purpose of this report is to describe the current state of economic knowledge with respect to prescribed fire. Because prescribed fire can be analyzed from a plethora of economic perspectives, there are several approaches to summarizing the literature. I have grouped the literature into three sections: cost, efficiency and damage.

Efficiency

With respect to efficiency, most research has been focused on fire management programs in their entirety rather than on individual aspects such as the efficiency of prescribed burning. For example, the economic tradeoffs between suppression and presuppression, and the cost effectiveness of various mixes of fire management activities such as initial attack, detection and fuels management. I have listed below, only the references that directly address the efficiency of prescribed burning.

Meredith, C. (1994). Is fire management effective? Fire and Biodiversity: the effects and effectiveness of fire management., Footscray, Melbourne, Department of the Environment Sport and Territories, Biodiversity Unit.

Almost every action of government is now subject to intense economic scrutiny and, where actions are not seen as cost-effective, they are likely to be reduced or modified. Despite this, the costs and benefits of the management of forest fires have received relatively little attention. There is remarkably little information to indicate the effectiveness of many fire management practices, let alone whether they have a positive cost-benefit ratio. The existing situation is reviewed and a series of questions posed. If the debate about appropriate structures for forest management and about the practicality and cost of conservation reserves versus harvested forests is to reach any conclusions, answers will be needed for these questions.

Moore, C. W., and Gayle M. Sitter (1987). Development and use of precise fire prescription to manage ecosystems economically and effectively. Ninth Conference on Fire and Forest Meteorology, San Diego, CA, American Meteorological Society.

This article investigates how fire can be used to meet the objectives of ecosystem management from an economic perspective. They conclude by stating that the use of precise prescriptions have become practical and economically feasible.

Costs

The majority of economic research with respect to prescribed fire has been centered on short-term and operational costs. The following articles address the cost of fuels treatment in relation to various benefits depending upon fire management objectives. It is important to note that there is a serious lack of research with respect to long-term costs and the effects of prescribed burning on total fire management efforts. This would be an area well worth exploring in the future.

Bell, E., David Cleaves, Harry Croft, Susan Husari, Ervin Schuster, and Dennis Truesdale. (1995). Fire Economics Assessment Report, USDA Forest Service.

The rising cost of fire suppression activities prompted the Regional Fire Directors, under the leadership of the Director of Fire and Aviation Management, to review the causes of these increased costs and recommend appropriate actions. The Fire Economics Assessment report is one of a series of reviews and reports following the 1994 fire season. The team found that the real expenditures for fire suppression have not increased since 1970 if 1994 expenditures are excluded, and that real expenditures for presuppression activities and fuel treatments have declined over the past 25 years. This report summarizes the team's deliberations and identifies a number of opportunities to reduce costs including the use of prescribed fire. It also identifies how current policy and direction will only increase costs, not reduce them.

Rideout, D. B., and Philip N. Omi (1995). "Estimating the Cost of Fuels Treatment." Forest Science 41(4):

664-674.

The authors develop a potentially generalizable cost estimation procedure for fuels treatment using the National Park Service nationwide database. The cost estimation procedure focuses on a constant elasticity of declining unit cost with increases in scale. Using multiple regression techniques, they test and confirm the hypotheses that the constant elasticity estimate can be applied to treatments intended to reduce fuel hazards or to treatments preferred for ecosystem management objectives.

Foley, W. T. (1992-1993). "A new way to analyze prescribed fire costs." Fire Management Notes. **53-54(4)**: 8.

This is a short article examining the relevant costs and benefits to include in a cost benefit analysis with respect to prescribed fire.

Nichols, H. T. (1988). Cost and benefits of prescribed fire in the national park service. Society of American Forester's 188 Convention: Healthy Forests, Healthy World, Rochester, NY, Society of American Foresters.

Since 1968, the National Park Service has used prescribed fire as a fire management strategy. After 20 years, some conclusions may be drawn regarding the quantitative and qualitative costs and benefits of prescribed fire. Such costs include not only the operational expenses but also more hidden costs such as research, planning, staffing, training, public education, and monitoring fire behavior and effects.

Gonzalez-Caban, A., and Charles W. McKetta (1986). "Analyzing fuel treatment costs." Western Journal of Applied Forestry **1**: 116-121.

Economically sound decisions on fuel treatment require knowledge of treatment costs. Fuel treatment costs derived using an economic cost concept on two National Forests were found to be higher than reported by accounting methods. Costs are sufficiently high and variable to question the economic feasibility of fuel treatments. Regression analysis did not show a strong relationship between fuel treatment costs and the physical characteristics of treatment sites. Management behavior and organization constraints may more successfully explain the magnitude and variability of fuel treatment costs. There are economies of scale in larger fuel treatment projects. Fuel managers emphasized hazard reduction over silvicultural objectives but believe that hazard targets could be achieved with lower fuel treatment levels.

Jackson, D. H., Patrick Flowers, Robert S. Loveless Jr., and Ervin G. Schuster. (1982). "Predicting prescribed burning costs of wildlife habitat management." Fire Management Notes **43(4)**: 20-22.

Two cost equations are now available to land managers for predicting prescribed burn costs for wildlife habitat improvement and assessing the costs of national forest land management required by law. Reported here in summary form are two cost equations that estimate the total project cost and cost per acre of prescribed burns. Our sample consisted of burns conducted for wildlife habitat improvement during fiscal years 1979 and 1980 in Region 1 (Montana and Northern Idaho) of the U.S. Department of Agriculture's Forest Service. Following the equations is a demonstration of how one of them might be used to estimate project cost.

Vasievich, M. J. (1980). Costs of Hazard-Reduction Burning on Southern National Forests. Southern Journal of Applied Forestry. **4(1)**: 12-15.

Prescribed burning plans from national forests on the southern coastal plain provide sufficient data to estimate the costs of burns that were completed as planned. Estimated costs over a 4-year period in 1976 dollars ranged from $4.82 per acre for a 50-acre burn in a 12-year rough to $0.35 per acre for a 2,400-acre burn in a 4-year rough. Cost per acre was strongly influenced by the size of burn and age of rough (years since last burn).

Damage/NVC

Damage, also known as net value change (NVC) in the cost plus net value change (C+NVC) theory of wildfire management is a major concern for fire managers. Mitigating damages by reducing fuel loading and associated hazards is one of the objectives of prescribed fire. Although there has been considerable

research done in this area with respect to specific resources such as recreation, the overall effects of prescribed fire on long-term damage, both physical and financial has not yet been fully explored.

Cleaves, D. A. (1985). Net Value Changes in Fire Management: Issues and Application Problems. Fire Management: The Challenge of Protection and Use, Utah State University, Utah State University, Dept. of Forest Resources, Intermountain Society of American Foresters Intermountain Region and Forest Service National Wildfire Coordinating Group.

Determining and interpreting net value changes are the most perplexing tasks in implementing economic efficiency policies in fire management. Frustration is caused by a lack of quantified information about physical and biologic fire effects and how these effects relate to fire behavior. In addition, planners are uncertain about how the effects should be translated into dollar values. This paper describes some of the problems that have arisen in measuring and predicting net value change (NVC) for fire management analysis, interprets the available methods for handling these problems, and explains the role of subjective judgment in estimating net value changes.

RISK and UNCERTAINTY

Liability

Because the use of prescribed burning entails risk of escape and damage, the issue of liability has significant implications for how prescribed burning is implemented and who is held accountable for projects that fail. Liability will significantly affect Forest Service policy regarding the implementation and associated costs of prescribed fire projects, perhaps making them prohibitively costly. These issues are discussed by Cleaves in the following article.

Cleaves, D. A., and T.K. Haines (1995). Regulation and liability risk: influences on the practice and the pricetag of prescribed burning. Environmental Regulation & Prescribed Fire: Legal and Social Challenges, Tampa, FL, Center for Professional Development, Florida State University.

About 4.4 million acres of forestland in the South are prescribed burned each year. In some states, the area burned has been decreasing steadily. Some industrial owners plan to burn less in the future because of increased regulation and liability risks associated with burning, higher prices and better utilization standards for wood residues, and the availability of chemical and mechanical alternatives to burning. The demand for burning by non-industrial private forestland owners cannot be met because of shrinking state agency funds for state conducted burns and shortages of insured burning contractors. However, burning on public lands has been increasing; ecosystem assessments, national forest plans, and endangered species recovery efforts call for further increases.

The cost of prescribed burning has risen more than twofold since 1982 - twice the rate of inflation and more rapidly than the costs of other silvicultural and wildfire hazard reduction practices. Some of this increase has been due to air quality regulations and the risks of liability of accidents, smoke intrusions, or escaped fires. So-called "certified burner" laws have been passed in five states to limit liability for qualified burners.

Managing risk

Risk management is an important aspect of fire management and planning because of the erratic nature of fire behavior. Similarly, because there is a risk of prescribed fires escaping, the public adds another confounding dimension to fire management. There have been a number of studies done on the public's perceptions of risk and how this influences fire policy, as well as how to estimate and model the physical aspects risk and fire management.

Cleaves, D. A., and T.K. Haines (1995). Regulation and liability risk: influences on the practice and the pricetag of prescribed burning. Environmental Regulation & Prescribed Fire: Legal and Social Challenges, Tampa, FL, Center for Professional Development, Florida State University.

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the future because of increased regulation and liability risks associated with burning, higher prices and better utilization standards for wood residues, and the availability of chemical and mechanical alternatives to burning. The demand for burning by non-industrial private forestland owners cannot be met because of shrinking state agency funds for state conducted burns and shortages of insured burning contractors. However, burning on public lands has been increasing; ecosystem assessments, national forest plans, and endangered species recovery efforts call for further increases. The cost of prescribed burning has risen more than twofold since 1982 - twice the rate of inflation and more rapidly than the costs of other silvicultural and wildfire hazard reduction practices. Some of this increase has been due to air quality regulations and the risks of liability of accidents, smoke intrusions, or escaped fires. So-called "certified burner" laws have been passed in five states to limit liability for qualified burners.

Cleaves, D. A. (1994). Assessing uncertainty in expert judgments about natural resources. New Orleans, LA, Southern Forest Experiment Station, USDA Forest Service.

All natural resource management decisions involve some uncertainty. Quantitative analysis can indicate possible consequences of some—but not all—proposed actions. Moreover, quantitative analyses can be unacceptably expensive, or of poor quality, or not informs usable in managerial and political decision processes. Given the limitations of analytical models and published studies, it may be necessary or desirable to directly elicit judgments from scientists and specialists. Many sources of uncertainty can influence these judgments. Decision-makers may be forced to choose among alternatives that embody unexpressed judgmental uncertainties. When uncertainties are not expressed properly, those who develop or choose among alternatives can be misled. A working definition of uncertainty and a rationale for quantifying uncertainty are presented, and general strategies and guidelines for estimating uncertain quantities, values, relationships, and events are offered here.

Williams, J. T. and. D. L. Bunnell. (1989). A method to measure and assess risk in prescribed fire programs. Proceedings: Prescribed fire in the Intermountain Region, Washington State University.

Risk aversion and risk-taking postures both tend to increase burning costs over time. An objective assessment of risk may provide the means to more effectively recognize, evaluate, and communicate the elements that contribute in defining the probabilities of gain or loss. Calculated risk and the applied results can provide the foundation for consistent cost-efficiency programs at planning and operational phases of the fuel treatment job. This paper presents a technique to approximate the relative level of risk between projects and array the economic implications of a chosen level of risk based on inferred probabilities of escape.

Baumgartner, D. C., and Robert J. Marty (1988). Evaluation of resources at risk from wildland fires. East Lansing, MI, North Central Forest Experiment Station, USDA Forest Service.

To properly allocate wildfire control resources among various wildland fire control districts of a state, it is necessary to estimate the value at risk from wildfire for each district and to compare them. The objective of this paper is to show how existing information can be used to establish values for timber and structures and to assess the potential for large wildland fires in representative counties of northern lower Michigan. These values combined with an assessment of the potential for large fires can then be used to provide a preliminary indicator of where fire protection efforts should be concentrated.

Bernardo, D. J., D.M. Engle, and E.T. Mccollum (1988). "An economic assessment of risk and returns from prescribed burning on tallgrass prairie." Journal of Range Management, 41(2): 178-183.

A stochastic (Monte Carlo) simulation model was developed to evaluate the influence of prescribed burning on the expected value and variability of net returns from a representative stocker cattle enterprise. The model was applied to both shallow prairie and eroded prairie range sites in eastern Oklahoma. Prescribed burning is shown to be an economically feasible means of improving the productivity of eastern red cedar infested rangeland. Implementation of an annual burning program results in a $69.00 and $4.80 per hectare increase in the net present value for the 10-year return stream generated from stocker cattle production on shallow prairie and eroded prairie range sites, respectively. Prescribed burning does not increase the variability of annual

income from stocker cattle production. However, when risk is measured in terms of relative variability (coefficient of variation) or the probability of annual returns below zero, prescribed burning is determined to be a risk-reducing practice.

Mills, T. J., and Frederick W. Bratten (1988). Economic efficiency and risk character of fire management programs, Northern Rocky Mountains. Berkeley, CA, Pacific Southwest Forest and Range Experiment Station, USDA Forest Service.

Economic efficiency and risk have long been considered during the selection of fire management programs and the design of fire management policies. The highly stochastic behavior of the fire system and the high degree of interaction among its components make it difficult to model analytically. This paper reports tests of three hypotheses about fire performance to analyze economic efficiency and risk performance of alternative fire management programs by using FEES. The economic efficiency and risk characteristics of several alternative fire management programs were estimated to test these hypotheses.

Saveland, J. M. (1987). Using prescribed fire to reduce the risk of large wildfires: a break-even analysis. Ninth Conference on Fire and Forest Meteorology, San Diego, CA, American Meteorological Society.

The author explores prescribed burning as an alternative to reducing the risk of large wildfires. This paper examines the monetary tradeoffs of investing in a prescribed fire program in natural fuels to reduce the probability of large, costly fires.

Saveland, J. M. (1985). Risk in Fire Management. Fire Management: the Challenge of Protection and Use, Utah State University, Intermountain Society of American Foresters Intermountain Region.

The amount of wildfire protection and prescribed fire use is largely determined by the individual decision-maker's propensity for accepting risk. This purpose of this paper is to provide an introduction to risk assessment and hopefully generate more interest in risk management, thereby increasing the cost effectiveness of fire management programs.

Blattenberger, G., William F. Hyde, and Thomas J. Mills (1984). Risk in fire management decision making: techniques and criteria. Berkeley, CA, Pacific Southwest Forest and Range Experiment Station, USDA Forest Service.

Methods for assessing the impact of fire on forest recreation were studied in a literature search and an experiment. Contingent market valuation appeared the most promising. This direct, economic approach uses personal interviews and sets up a hypothetical market transaction in which values are estimated. In an illustrative application of this method, respondents were shown sequences of photographs of recreation sites depicting scenes before and after a fire. They were asked about their preferences among the scenes depicted and about their willingness-to-pay an entrance fee to the preferred sites. The example results suggest that less intense fires may have beneficial economic impacts on recreation values, whereas intense fires may have adverse effects. The valuation of the impact of fire among recreationists is not always negative or unanimous and preferences may change over time.

Mills, T., J. (1982). FEES: design of a Fire Economics Evaluation System. F. W. Bratten. Berkeley, CA, Pacific Southwest Forest Range and Experiment Station, Forest Service, USDA: 26.

The Fire Economics Evaluation System (FEES) - a simulation model - is being designed for long term planning application by all public agencies with wildland fire management responsibilities. A fully operational version of FEES will be capable of estimating the economic efficiency, fire-induced changes in resource outputs, and risk characteristics of a range of fire management program options. Risk is described by the probability distributions of economic efficiency and resource output changes that result from annual variation in factors such as fire occurrences and fire weather. Particular attention is given to the fuel treatments, initial attack, and large fire suppression portions of the fire management program. FEES evaluates the performance of fire management program options as they are applied to particular fire management "situations," described by parameters which influence program performance, such as vegetation, topography, resource management objective, and fire occurrence levels. Location is addressed only through the regional fire climate zone. The situation-specific design, as opposed to location- or site-

specific design, was chosen to avoid duplication of data collection and analysis costs. Duplication costs occur when site-specific planning models are applied independently to planning areas even though the characteristics of the area which influence fire program performance are essentially the same.

Bratten, F. W. (1982). Probability model for analyzing fire management alternatives: theory and structure. Berkeley, CA, Pacific Southwest Forest and Range Experiment Station.

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WILDLAND-URBAN INTERFACE and RISK

Wildland-urban interface

As the number of people living near forested or wilderness areas increases, so too does the risk of damage from wildfire. Managers and society alike must be aware of the dangers posed by fire and derive management plans to deal with it effectively. The following articles present a range of issues and concerns, as well as possible solutions to the problems created within the wildland-urban interface.

(1994). The Biswell Symposium: Fire Issues and Solutions in Urban Interface and Wildland Ecosystems. The Biswell Symposium: Fire Issues and Solutions in Urban Interface and Wildland Ecosystems, Walnut Creek, California, Pacific Southwest Research Station.

This symposium deals with a myriad of fire issues including the barriers to fuels management, a panel discussion dealing with prescribed burning in the 21st Century, urban interface topics, regional approaches to urban interface problems and potential solutions.

Anonymous (1997). Arizona's Wildland - Urban Interface, National Forest Fuels Reduction Treatment Proposals, May 1997.

This article deals with the increasing number of people living in the wildland-urban interface and presents examples from each of the six national forests in Arizona. The author indicates the type of work needed to reduce the potential for a wildfire catastrophe in each case.

Lavin, M. J. (1997). "Managing Fire Risk to People, Structures, and the Environment." Fire Management Notes. **57**(4): 4-6.

The author recognizes the increasing threat posed to people living in the wildland-urban interface and advocates that risk can be managed. Efforts to reduce the risk of fire include identification of high-hazard areas, fuel modification and reduction, prevention, training and education.

Anonymous (1995). Course to the future: positioning fire and aviation management. Washington, DC, Fire and Aviation Management, USDA Forest Service.

This report is a response to a particularly damaging fire year in 1994, and draws on several agency reports. It's recommendations for the wildland/urban interface is: renegotiate state and

local cooperative fire agreements with partners at the wildland/urban interface to clarify protection responsibilities. Phase out as primary protection agency in urbainzed and developing rural areas.

Williams, J. T., R.G. Schmidt, R.A. Norum, P.N. Omi, and R.G. Lee (1993). Fire related considerations and strategies in support of ecosystem management., USDA Forest Service, Washington Office.

The authors make five recommendations for wildfire policy and expansion of the prescribed fire program in light of ecosystem management. With respect to the wildland-urban interface, they suggest that avoiding treatment will pose a growing threat to the wildland/urban interface values where development is occurring in fire prone types. Policy recommendations are include action plans and an examination of economic and internal issues.

Gardner, P. D., and Hanna J. Cortner (1985). Public risk perceptions and policy response toward wildland fire hazards in the urban/rural interface. Fire Management: the Challenge of Protection and Use, Utah State University, Intermountain Society of American Foresters Intermountain Region.

People living in the urban interface face increasing risk of damage due to fire. The authors develop a model to quantitatively assess risk and discuss policy alternatives acceptable to homeowners.

Public Perceptions and Risk

One of the greatest management difficulties with respect to prescribed burning is the public's perception of risk and the implications of fire policy. Smoke, risk of escape and aesthetics are all negative factors associated with prescribed burns which makes public acceptance and support for prescribed burning programs difficult to obtain. The following articles review the public's perception of risk associated with fire, and explore alternative management polices.

Bright, A. D. (1995). Influencing public attitudes toward prescribed fire policies. Environmental Regulation & Prescribed Fire: Legal and Social Challenges, Tampa, FL, Center for Professional Development, Florida State University.

This paper reviews public attitudes toward prescribed fire policies and discusses the application of advancements in persuasion theory to communication programs. Results of improved communication include informed public involvement and greater understanding and support of prescribed fire policies.

Gardner, P. D., and Hanna J. Cortner (1985). Public risk perceptions and policy response toward wildland fire hazards in the urban/rural interface. Fire Management: the Challenge of Protection and Use, Utah State University, Intermountain Society of American Foresters Intermountain Region.

This paper develops and quantifies a conceptual model for determining how risky wildland fire hazards are believed to be by homeowners in the urban-rural interface. They discuss what kinds of policy alternatives homeowners prefer for dealing with potential fire hazards.

Beebe, G. S., and P.N. Omi (1993). "Wildland burning: the perception of risk." Journal of Forestry, 91: 19-24.

Beebe and Omi explore how public perception of risk is shaped and offer some implications about wildfire when it becomes headline news.

Flowers, P. J., Henry J. Vaux, Jr., Philip D. Gardner, and Thomas J. Mills (1985). Changes in recreation values after fire in the northern Rocky Mountains. Berkeley, CA, Pacific Southwest Forest and Range Experiment Station, USDA Forest Service.

Changes in recreation values after wildfire in the northern Rocky Mountains were determined by estimating the difference in the present net value of recreation activity with and without fire. To estimate the value of recreation activity at burned and unburned sites, a contingent market valuation approach was used. Hypothetical market transactions were created by soliciting bids from recreationists, which they based on photographs of recreation sites depicting scenes before and after two kinds of fire - one of low intensity and the other of high intensity. They were asked

what they would pay for the situation they most preferred. The results suggest that net value changes in recreation resources are generally low, and possibly insignificant in economic efficiency analyses of fire management programs.

Vaux, H. J. J., Philip D. Gardner, and Thomas J. Mills (1984). Methods for assessing the impact of fire on forest recreation. Berkeley, CA, Pacific Southwest Forest and Range Experiment Station, USDA Forest Service.

Efforts to evaluate the effects of fire on natural resources have focused largely on impacts that are commonly measured in monetary terms, such as losses of commercial timber, grazing yields, and structures. The effects on the generally unmarketed resources, such as watershed, fish, wildlife, and recreation, have been considered in policy directives, but the economic implications of the effects of fire on these forest amenities have not been fully understood. These latter resource categories have figured less prominently in fire management program evaluations partly because they are not usually traded in markets. Recreation is one resource that is least subject to market allocation, and the economic literature on outdoor recreation presents a varied and sometimes conflicting array of conclusions. Investigators have reached no consensus on the magnitude of recreation benefits or the appropriate methodologies for estimating these benefits. Successful attempts to isolate the value of individual attributes of the outdoor recreation experience have been few. Efforts to assess the impact of fire on recreation usage and value are even more sparse. The fact that fire affects only selected site attributes, and also affects the path of those attributes over time further confounds the measurement problem (Davis and others 1980). This report assesses the degree to which current methods for measuring recreation demand are sensitive to quality differences caused by fire in different forest environments, and recommends methods for estimating recreation demands and values in a fire-affected situation.

Anderson, L. M., Daniel J. Levi, Terry C. Daniel, and John H. Dieterich (1982). The esthetic effects of prescribed burning: a case study, Rocky Mountain Forest and Range Experiment Station, USDA Forest Service.

The authors compare scenic values for two ponderosa pine plots where one plot has been burned. They conclude that the burned plot was significantly more attractive 1 year later. They state that knowledge of the effect of prescribed burning on scenic quality will result in improved forest management decisions.

Smoke

Roger Ottmar is conducting current research on the effects of smoke from prescribed fires at the Pacific Northwest Research Station. Note, a listing of research projects can also be found in the research section in the latter part of this report.

Ottmar, R. D. (1986). Reducing smoke from prescribed fires: research solution to a management problem., USDA Forest Service.

The author looks at the opposing objectives of the forester and the air resource managers and questions whether this potential conflict will lead to a reduction in the number of acres burned. This paper updates research progress by the USDA Forest Service Fire and Air Resource Management Project in the areas of fuel consumption, emission characterization, and emission reduction.

HAZARD, FUELS MANAGEMENT and MODELING

Hazard and Fuels Management

Hazard, as opposed to risk, refers to physical properties such as fuel loading and fuel characteristics that may give rise to more severe and intense fires once they are ignited. Although removing or reducing the hazard component will not change the probability of a fire being ignited, it may significantly reduce the possibility of a fire becoming uncontrollable. The following articles pertain to fuels management for the purpose of reducing hazardous accumulations of forest fuels.

Hirsch, S. N., David L. Radloff, Walter C. Schopfer, Marvin L. Wolfe, and Richard F. Yancik (1981). The activity fuel appraisal process: instructions and examples. Fort Collins, CO, Rocky Mountain Forest and Range Experiment Station, USDA Forest Service.

Radloff, D. L., Richard F. Yancik, and Kenneth G. Walters (1982). User's guide to the national fuel appraisal process. Fort Collins, CO, Rocky Mountain Forest and Range Experiment Station, USDA Forest Service.

The preceding two articles provide a quantitative process for appraising fire hazard from activity fuels by combining fire- and fuel-modeling with decision analysis principles to produce an estimate of expected burned area. Expected fire occurrence, climate, fuel loads, fire behavior, and suppression capability are considered in the fuel appraisal process.

Anonymous (1997). Arizona's Wildland - Urban Interface, National Forest Fuels Reduction Treatment Proposals, May 1997.

This article states that the real cost of wildfires needs to be defined and publicized, and the effort should also define the cost/benefit ratios for fuel management programs. The author presents examples from each of the six national forests in Arizona indicating the type of work needed to reduce the potential for a wildfire catastrophe.

Fuel Modeling

Fuel modeling is an important aspect of prescribed fire management because it enables fire managers to estimate the physical effects of alternative prescriptions on the amount of fuels remaining after a fire. The following articles describe models and method to appraising forest fuels to predict fire behavior.

Andrews, P. L. (1986). BEHAVE: Fire behavior prediction and fuel modeling system--BURN subsystem, part 1. Ogden, UT, Intermountain Research Station, USDA Forest Service.

Brown, J., K., and Dennis G. Simmerman (1986). Appraising Fuels and Flammability in Western Aspen: a Prescribed Fire Guide. Ogden, UT, Intermountain Research Station, USDA Forest Service.

Harrington, M. G. (1987). Predicting reduction of natural fuels by prescribed burning under ponderosa pine in southeastern Arizona., USDA Forest Service.

Harrington, M. G. (1982). Stand, fuel and potential fire behavior characteristics in an irregular southeastern Arizona ponderosa pine stand., USDA Forest Service, Rocky Mountain Forest and Range Experiment Station.

Harrington, M. G. (1981). Preliminary Burning Prescriptions for Ponderosa Pine Fuel Reductions in Southeastern Arizona. Fort Collins, Rocky Mountain Forest and Range Experiment Station, Research Work Unit in Tempe, in cooperation with Arizona State University.

Norum, R. A. (1977). Preliminary guidelines for prescribed burning under standing timber in western larch/douglas-fir forests, USDA Forest Service, Intermountain Forest and Range Experiment Station.

Although neither study includes an economic analysis, the two articles present burn prescriptions for the purpose of hazard reduction. The articles include guidelines for safe, effective fire treatments.

DECISION MAKING AND COMPUTER ANALYSIS

Computer models that provide information regarding fire behavior aid decision making with respect to prescribed fire. Although most models are designed to assess the effects of suppression and the physical outcomes resulting from fire, they may prove useful in the application of prescribed fire.

Computer models—economic aspects

Although most computer models have been designed and are used for fire management planning with

respect to suppression, the structure of these models is such that it is possible to evaluate the economic effects of prescribed fire as well. Mills and Bratten (1982, 1988) specifically incorporate economic objectives into the FEES model, and Bratten (1982) incorporates risk into a fire management model.

Mills, T.J., and F. W. Bratten. (1988). Economic efficiency and risk character of fire management programs, Northern Rocky Mountains. Pacific Southwest Forest and Range Experiment Station, USDA Forest Service: Berkeley, CA.

Mills, T., J., and F. W. Bratten. (1982). FEES: design of a Fire Economics Evaluation System. Berkeley, CA, Pacific Southwest Forest and Range Experiment Station, Forest Service, USDA, 26 pp.

FEES is a long-term planning simulation model that is capable of estimating economic efficiency, fire-induced changes in resource outputs, and risk characteristics of a range of fire management program options. Particular attention is given to the fuel treatments, initial attack, and large fire suppression portions of the fire management program.

Bratten, F. W. (1982). Probability model for analyzing fire management alternatives: theory and structure. Berkeley, CA, Pacific Southwest Forest and Range Experiment Station.

Wildland fire management programs are increasingly judged by their economic efficiency. Given the variable nature of wildfires, planners have recognized the probabilistic nature of fire. This report described the mathematical structure of the probability model and the logic behind a system for analyzing wildfire fire management.

Computer models—fire behavior

Various computer models have been developed to estimate the physical effects of fire and to design prescriptions based on relevant weather and fuels information. They rely on state of the art prediction models to predict fire behavior and resulting changes in ecosystem characteristics. Fire behavior predictions are based on information such as flame length, intensity, area burned, etc, and are used to address a broad range of management objectives.

Finney, M. (1996). *FARSITE™ Fire Area Simulator version 1.0 User's guide and technical documentation.* Systems for Environmental Management: Missoula, MT 116 pp.

Schlobohm, P.M., *Use a comparison model to guide technology decisions.* Fire Management Notes., 1996. 56(1): p. 12-14.

Reinhardt, E. (1991). Computerized development of fire prescriptions. School of Forestry, Missoula, University of Montana, 108 pp.

Andrews, P. L., and Larry S. Bradshaw (1990). RXWINDOW, defining windows of acceptable burning conditions based on desired fire behavior. Ogden, UT, Intermountain Research Station, USDA Forest Service.

Andrews, P. L. (1986). BEHAVE: Fire behavior prediction and fuel modeling system--BURN subsystem, part 1. Ogden, UT, Intermountain Research Station, USDA Forest Service.

Bevins, C. D., and William C. Fischer (1983). A computer system for testing fire management prescriptions. Part 2—computer terminal operator's manual. Ogden, UT, Intermountain Forest and Range Experiment Station, USDA Forest Service.

This report outlines the structure of a user-oriented computer system that allows fire managers to examine computerized historical fire-occurrence and weather records and identify ignitions that would have qualified as prescribed fires according to the conditions of a test prescription.

Bradshaw, L. S., and William C. Fischer (1981). A computer system for scheduling fire use. Part II: computer terminal operation's manual. Ogden, UT, Intermountain Forest and Range Experiment Station, USDA Forest Service.

Information

The information systems described below will improve fire behavior and weather information used to formulate fire prescriptions and wildfire suppression. Although they do not all directly incorporate economic objectives, this information may be usable in future economic analysis to improve agencies' tactical and strategic efficiency.

Fire 21

The concept of *Fire 21* was developed as a result of wildland fires occurring in 1994. To better communicate their message, the Forest Service Fire and Aviation managers have adopted a strategy to improve firefighter and public safety, enhance ecosystem health, improve economic accountability, enact safe and cost-effective management program and to integrate wildland fire management concerns where appropriate. The following articles pertain to this concept.

Burgan, R. E., and L. S. Bradshaw. (1997). "WFAS Requires a Variety of Weather Information." Fire Management Notes.. **57**(2): 18-21.

Anonymous, *Safe and effective use of wildland fire for the 21st century.* (1996), USDA Forest Service.

Apicello, M.G. (1996) *Fire 21 - Fire Management in the 21st Century.* Fire Management Notes.. **56**(3): p. 4-5.

Hamilton, S.F. (1996). *NASF's Perspective on FIRE 21.* Fire Management Notes. **56**(3): p. 6-8.

Lavin, M. J. (1996). *Leaders committed to FIRE 21.* Fire Management Notes. **56**(3): p. 6.

Burgan, R.E., P. L. Andrews, L. S. Bradshaw, C. H. Chase, R. A. Hartford, and D. J. Latham. (1996). Current Status of the Wildland Fire Assessment System (WFAS). Fire Management Notes.. **57**(2):14-17.

> *The Wildland Fire Assessment System will eventually combine the functionality of the current fire-danger rating system and the fire behavior system. The new system will assess fire potential across spatial scales. The output will be useful for fire management tasks ranging from strategic planning to current fire situation analysis.*

Eenigenburg, J. E., and William A. Main (1995). "METAFIRE--A timely accurate, and verified large-fire severity index." Fire Management Notes. **55**(2): 8-17.

Simard, A.J. (1990) *METAFIRE: A system to support high-level fire management decisions.* Fire Management Notes.. **51**(1):10-17.

> *METAFIRE is a weather data base covering the entire country and is used to analyze the effects of climatic and ecological processes on large fires. The system also links itself to higher resolution atmospheric meso-scale models for assessing the regional scale atmospheric impacts on wildland fire severity. Furthermore, FEMA uses the METAFIRE severity index to justify fire emergency funding requests.*

Parminter, J. (1989). Prescribed fire management information system - project 1.11. Victoria, BC, Ministry of Forests.

> *This system addresses the need for a method to assess the impacts of prescribed fires in logging slash. Information provides data for developing and refining prescribed burn planning models and decisions-making aids.*

Barrager, S. M., David Cohan, and Peter J. Roussopoulos (1982). The economic value of improved fuels and fire behavior information. Fort Collins, CO, Rocky Mountain Forest and Range Experiment Station, USDA Forest Service.

> *Presumably, better information about fuels and fire behavior would enable land managers to make better fire management decisions and, thereby, improve the efficiency of fire management programs. Improving information on fuels and fire behavior can be costly. It is necessary to*

balance the expected benefits with the costs of gathering or developing improved information. Although the specific models developed in this analysis are unique to the decisions and areas described, the general analysis approach can be useful in a large variety of resource management decision situations.

FOREST HEALTH and ECOSYSTEM MANAGEMENT

Forest health

Forest health is often dependent upon the presence or absence of fire, particularly for fire dependent ecosystems. Furthermore, the role of fire should either add to or detract from forest health resulting in measurable economic benefits. However, there has been very little economic analysis conducted with respect to the relationship between prescribed fire, economics and forest health. The following articles recognize the importance of prescribed fire as a management tool in meeting forest health goals, however, not from an economic perspective.

Anonymous (1996). America's Forests: 1996 Health Update. Washington, DC. USDA Forest Service. 1 page Map.

A one page map reviews critical forest health issues including the rural-urban-wildland interface and changing ecological conditions.

Anonymous (1996). Faces of Fire. Washington, DC, Fire and Aviation Management, USDA Forest Service. 19 pp.

A brief summary of the importance of prevention, suppression and prescribed fire as management tools to help ecosystem management, support forest health objectives and to protect and enhance natural resources.

Anonymous (1994). Western Forest Health Initiative. Washington, DC. State and Private Forestry, USDA Forest Service. 70 pp.

Review and summary of measures needed to restore forest health in stressed forests. The report begins with a background summary of current problems, reviews information gathering techniques and links to other initiatives. It proceeds with recommendations, affirmations, a list of projects and finally key recommendations.

Most journal articles and government documents regarding forest health recognize the role of fire as an essential ecosystem function in terms of effects on insects and disease, wildlife, habitat, and vegetation. However, they do not address the role of prescribed fire per se. Recent articles include:

United State Department of Agriculture. (1997). Forest Ecosystem Health In The U.S. (Final) Hearings Comm. On Agriculture... House Of Representatives... 105th Congress., 1st Session, June 5, 1997. Washington, D.C., U.S. Government Printing Office: 88.

Anonymous. (1996). Forest Health Monitoring. Research Triangle Park, NC, USDA Forest Service.

Mutch, R.W. (1994). *Fighting fire with prescribed fire: a return to ecosystem health.* Journal of Forestry, 92(11): p. 31-33.

Monnig, E., and James Byler (1992). Forest Health and Ecological Integrity in the Northern Rockies, USDA Forest Service, Northern Region.

Bechtold, W. A., William H. Hoffard, and Robert L. Anderson (1992). Summary Report, Forest Health Monitoring in the South, 1991. Asheville, NC, Southeastern Forest Experiment Station, USDA Forest Service.

Ecosystem management

Ecosystem management is a relatively new concept whereby management objectives are integrated on an ecological basis. For fire dependent ecosystems, the reintroduction and use of prescribed fire is an important issue in meeting such objectives. The following articles discuss the objectives of ecosystem management and list recommendations with respect to prescribed fire.

Anonymous (1996). Land management considerations in fire-adapted ecosystems: conceptual guidelines. Washington, D.C., USDA Forest Service, Fire and Aviation Management.

This guide is designed to be used to establish the framework and foundation in the Assessment Phase Cycle and to integrate fire management considerations into the succeeding steps of the Land Management Planning Cycle. It discusses the integration of fire into the management planning process, and recognizes the fact that ecosystems are in a continual state of change. Finally, the article discusses using prescribed fire to meet ecosystem management objectives.

Anonymous (1995). Course to the future: positioning fire and aviation management. Washington, DC, Fire and Aviation Management, USDA Forest Service.

This report draws on a wide group of recently completed Forest Service reviews, summaries and assessments, which reflect fire related issues and concerns. Listed are five key recommendations to improve firefighter safety and reduce large fire costs.

Boynton, J. (1994). Ecosystem management issues. in *The Biswell Symposium: Fire Issues and Solutions in Urban Interface and Wildland Ecosystems.* Walnut Creek, CA: Pacific Southwest Research Station.

Williams, J. T., R.G. Schmidt, R.A. Norum, P.N. Omi, and R.G. Lee (1993). Fire related considerations and strategies in support of ecosystem management., USDA Forest Service, Washington Office.

Due to changing ecosystem characteristics, and ecosystem management objectives, managers are finding it difficult to ensure sustainability. This article advocates the expansion of a prescribed fire program as a biologically sound way to restore sustainable conditions to help solve forest health problems in fire-adapted ecosystems. They make five recommendations.

Moore, C. W., and Gayle M. Sitter (1987). Development and use of precise fire prescription to manage ecosystems economically and effectively. Ninth Conference on Fire and Forest Meteorology, San Diego, CA, American Meteorological Society.

This article investigates how fire can be used to meet the objectives of ecosystem management from an economic perspective. They conclude by stating that the use of precise prescriptions have become practical and economically feasible.

FOREST SERVICE RESEARCH

This section summarizes documentation on the Internet regarding USDA Forest Service research with respect to prescribed fire. Most of the research pertains to fire behavior and physical effects. However, some projects include socio-economic effects and human components derived from the implementation of prescribed fire. Where appropriate I have included a brief description of the economic research objectives. Everywhere else, I have included only the title of the project and a summary of the general goals and objectives.

Forest Fire and Atmospheric Sciences Research Directory. United States Department of Agriculture, Forest Service, Washington, DC

This directory provides contact information for the international community, government and non-government organizations, university researchers, and state foresters. It also provides information for USDA Forest Service research administrators and scientists and others within the agency interested in Forest Fire and Atmospheric Sciences Research (FFASR). The directory lists names, telephone numbers, and postal and electronic mail addresses of research work units (RWU's) and highlights their activities and accomplishments.

http://www.fs.fed.us/research/ffasdir.html?prescribed+and+fire#FF2

Forest Service Research

The Forest Service conducts research at eight Forest and Range Experiment Stations, the Forest Products Laboratory, and the International Institute of Tropical Forestry. Over 700 scientists and other supporting personnel work at research work units (RWU's) at 77 locations throughout the United States, Puerto Rico, and the Pacific Trust Islands. Forest Service Research serves society by developing and communicating scientific information and technology needed to protect, manage, and use the renewable natural resources of the nation's 1.6 billion acres of forest and related rangelands.

The Forest Service Research strategic plan, "Strategy for the 90's for USDA Forest Service Research," provides direction for the research program. This strategic plan emphasizes three major program components:

- Understanding Ecosystems. Understanding the structure and function of forest and range ecosystems includes study of the mechanisms that control ecosystem processes and the interdependence of ecosystem components. Ecosystem research provides the scientific basis for addressing resource health and productivity.

- Understanding People and Natural Resource Relationships. Understanding how people perceive and value the protection, management, and use of natural resources is critical to managing these resources. Increased variety of resource uses and differing perceptions among user groups make reaching consensus a challenge.

- Understanding and Expanding Resource Options. This component focuses on determining which protection and management practices and utilization systems are most suitable for the sustainable production and use of natural resources. Special attention is on management options for water, fish, recreation use, and recycling wood fiber for new products.

To support and respond to the array of issues in the short and long term, Forest Service scientists pursue both basic and applied research. Current research programs improve resource productivity, reduce costs, enhance the effectiveness of forest management, and protect and improve environmental quality. In addition to research on current national issues, Forest Service Research has an institutional base of scientific and technological expertise for addressing long-term natural resource research needs of the U.S. and other parts of the world. It provides the scientific infrastructure necessary to respond to current and future problems as they emerge and includes many long term studies. These studies produce valuable

baseline data and often include several decades of accumulated information useful for studying the long term effects and trends of forest management activities. Research is conducted in the following fundamental areas: Forest Fire and Atmospheric Sciences; Forest Insects and Disease; Forest Management; Forest Environment; Forest Products and Harvesting; and Forest Inventory, Economics and Recreation.

Forest Fire and Atmospheric Sciences Research

Forest fire and atmospheric science research enhances the productivity and health of forest and range ecosystems. It determines how to control and use fire in a productive and safe manner, acquires fundamental knowledge of forest and atmospheric interactions, and objectively monitors and assesses the potential effects on forests caused by global changes in climate, air pollutants and other varying atmospheric factors.

In addition to a small Forest Fire and Atmospheric Sciences Research (FFASR) staff that coordinates research programs in the national headquarters in Washington, DC, there are 16 Forest Service fire or fire-related research projects located in ten locations throughout the United States. Much of the research is done in conjunction with colleges, universities, and other research facilities. Research work units conduct research in one or more of the following areas:

- fire behavior, physics, and chemistry
- role of fire in restoring and sustaining healthy forest and range ecosystems
- fire management, planning, and economics
- human dimensions of fire and ecosystem management
- fire meteorology and fire danger
- air resource management
- ecosystem response to atmospheric variability
- forest meteorology and climatology.

Forest Fire and Atmospheric Sciences Research (FFASR)
DIRECTOR: William T. Sommers
NAT'L HEADQUARTERS USDA Forest Service
TELEPHONE NUMBER: (202) 205-1561
FAX NUMBER: (202) 205-2497
ELECTRONIC MAIL: DG ADDRESS: W01C
INTERNET: fswa/s=w.sommers/ou=w01c@mhs.attmail.com

PURPOSE: To enhance the productivity and health of forest and range ecosystems. To improve methods for preventing, predicting, controlling, and reducing the damaging effects of wildfires. To determine how to use fire in a productive and environmentally sound manner. To acquire fundamental knowledge about forest-atmosphere interactions. To objectively monitor and assess potential effects on forests of global environmental change mechanisms, including climate, air pollutants, and other varying atmospheric factors.

SCOPE: National and international

NATIONAL PROGRAMS: Fire and Atmospheric Sciences
Fire research
Atmospheric Sciences Research
Global Change

RWU NC-4401Atmospheric and Socioeconomic Relations With Wildland Fire
PROJECT LEADER: Warren E. Heilman
ADDRESS: North Central Forest Experiment Station, 1407 S. Harrison Road, Room 220, East Lansing, MI 48823-5290
TELEPHONE NUMBER: (517) 355-7740
FAX NUMBER: (517) 355-5121

ELECTRONIC MAIL: DG ADDRESS: S23L03A
INTERNET: fswa/s=w.heilman/ou=s23L03a@mhs.attmail.com

KEY RESEARCH STUDIES:
Social and Economic Impacts of Fire in the Wildland-Urban Interface
We are using contingent valuation interview methods combined with socioeconomic data to assess the values that individuals place on the social and economic impacts of fire in the wildland-urban interface. Individuals' willingness to pay for incremental reductions in the risk of experiencing a loss is being examined to develop wildfire risk reduction value functions. The development of such functions is critical for policy makers in committing to costly investments in wildfire risk reduction programs.

Literature Synthesis of Conceptual Models Related to the Human Dimension of Ecosystem Management
We are conducting a literature synthesis of existing conceptual models as they relate to the human dimension of ecosystem management. This synthesis will provide the foundation for developing the unit's social science research program. We are also conducting a synthesis of the collaborative planning literature as it relates to ecosystem management to assess collaborative planning methods and their application to forest management problems, and to provide a more holistic approach to public involvement in forest management decision making.

RWU FPL-4718 Fire Safety of Wood Products
PROJECT LEADER: Robert H. White
ADDRESS: Forest Products Laboratory, 1 Gifford Pinchot Drive, Madison, WI 53705-2398
TELEPHONE NUMBER: (608) 231-9265
FAX NUMBER: (608) 231-9303
ELECTRONIC MAIL: DG ADDRESS: S32A
INTERNET: fswa/s=r.white/ou=s32a@mhs.attmail.com

KEY RESEARCH STUDIES:
Wildland-Urban Interface
Increasing movement of people into the wildland-urban interface areas raises a national concern regarding losses due to wildland fires. Our project is working cooperatively with other FFASR units of the Forest Service, namely, the PSW Forest Fire Laboratory in Riverside, CA, and the Southern Forest Fire Laboratory in Macon, GA. Recent work has concentrated on developing better data and models for the ignition of exterior siding materials. Proposed research includes cooperative testing of different types of landscape vegetation for flammability.

RWU INT-4403-Fire Effects and Prescribed Fire
PROJECT LEADER: Kevin Ryan
ADDRESS: Intermountain Fire Sciences Laboratory, PO Box 8089, Missoula, MT 59807
TELEPHONE NUMBER: (406) 329-4800 or 329-4803
FAX NUMBER: (406) 329-4877
ELECTRONIC MAIL: DG ADDRESS: S22L01A
INTERNET: fswa/s=k.ryan/ou=s22L01a@mhs.attmail.com

MISSION: To determine the effects of fire on forest, range, and wilderness ecosystems and to develop guides and computer information systems for applying fire effects knowledge to the planning, execution, and evaluation of prescribed fire.

SCOPE: National and international. International cooperation involves Canada (fuel consumption), Portugal and France (tree mortality and fuel modeling).

KEY RESEARCH STUDIES
Biological Conditions Before and Responses Following Fire
Prescribed Fire for Restoration and Maintenance of Ecosystems
Prescribed Fire Information Systems
Characterization of Fire Regimes

PNW-4451 and 4455-Fire and Environmental Research Applications (FERA)
TEAM CONTACT: Roger D. Ottmar
ADDRESS: Pacific Northwest Research Station, 4043 Roosevelt Way, NE, Seattle, WA 98105-6497
TELEPHONE NUMBER: (206) 553-7815
FAX NUMBER: (206) 553-7709
ELECTRONIC MAIL: DG ADDRESS: R06F05A
INTERNET: fswa/s=r.ottmar/ou=r06f05a@mhs.attmail.com

KEY RESEARCH STUDIES:
Fire and Ecosystem Management Under a Changing Climate
Forest management has often suppressed natural disturbances to provide stability, but this has inadvertently disposed forests to more severe disturbances. Fuel consumption and severity predictions during wildfires and prescribed fires in natural fuel complexes are needed to anticipate the impacts of fire on ecosystems. The information is essential to improved modeling of ecosystem dynamics under a changing climate scenario.

Risk Assessment for Human Health Hazards
Laws and regulations on environmental quality and occupational safety require management of human exposure to toxic air pollutants within specific limits of concentration and duration. We have completed three years of a five year comprehensive assessment of firefighter exposure to smoke during prescribed fires and wildfires. A final report has been completed on the prescribed fire portion of the study. The resulting information will be used to develop a health risk assessment and risk management strategies for firefighters.

RWU PSW-4402-Fire Management in the Wildland-Urban Interface
PROJECT LEADER: Richard Kimberlin
ADDRESS: Pacific Southwest Forest Fire Laboratory, 4955 Canyon Crest Drive, Riverside, CA 92507-6099
TELEPHONE NUMBER: (909) 680-1524
FAX NUMBER: (909) 680-1501
ELECTRONIC MAIL: DG ADDRESS: ECON:S27L05A
INTERNET: fswa/s=f.fujioka/ou=s27L05a@mhs.attmail.com

KEY RESEARCH STUDIES:
Helping Fire and Resource Managers Make Decisions
Fire and resource managers today must attempt to consider an array of resource, environmental, social, political, economic, and fire behavior parameters when making fire management decisions. Through the use of technology such as geographic information systems, expert systems, risk analysis, and modeling, we will look at ways to improve the availability and usefulness of complex data to decision makers. Specifically, we will:

- develop dynamic models for fire growth and fire suppression effectiveness using complex terrain, weather, and fuels data. These will help fire managers evaluate how well alternative fuels management and fire suppression strategies and tactics meet land and resource management objectives,
- analyze the influence of social and non-commodity values in fire management decisions and develop methods to integrate their consideration with market resource values in fire management benefit-cost and risk analyses,
- develop ways to use seasonal fire weather forecasts in making decisions about fire management budgets and allocating protection forces to maximize regional and national fire program efficiency.

Developing a Model to Help Minimize Risk to Structures from Wildland Fires
Houses in areas of flammable wildland fuel are often not located, constructed, or maintained to minimize the risk of their ignition when there are wildfires in the surrounding vegetation. In one study, we are developing a computer model to assess the potential for structures to ignite from wildland fire. The model is based on specific characteristics of a site, the surrounding fuels, and the planned or existing structure. Information from this assessment will help guide developers and home owners in the construction and maintenance of fire-safe homes in wildlands and help them mitigate potential fire-related problems.

Investigating Methods to Forecast Management Impacts
We are also investigating how population growth and changes in land use patterns will impact fire management. Our objective is to provide insights into future mitigation needs for zoning, residential development, fuels management, and fire protection planning.

RWU PSW-4403 Prescribed Fire Research
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KEY RESEARCH STUDIES:
The Effects of Prescribed Fire on the Environment
Prescribed fire can have varying effects on the environment depending on vegetation condition and fire behavior. Our research is directed towards better understanding the linkages between prescribed fire behavior and the resulting effects. We conduct studies examining:

- fire uses for ecosystem management, restoration, and protection,
- fire ecology of temperate and tropical ecosystems,
- fire, deforestation, and global change,
- plant physiology and fire effects relationships,
- fire-generated heat transfer through soil,
- heat effects on vegetation,
- prescribed fire behavior,
- fire behavior in live fuels,
- fuel arrangement and availability,
- fire-pest interactions.

We also assist natural resource managers by producing materials that deal with:

- fuel models and guides,
- prescribed fire guidelines,
- fire behavior and effects.

RWU PSW-4451-Atmospheric Deposition Effects on Montane Forests in the Western United States
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RWU PNW-4362 and 4163-Eastside Ecosystem Management Research
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RWU PSW-4401-Meteorology for Fire Severity Forecasting
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RWU PSW-4352-Ecology and Fire Effects in Drought-Prone Ecosystems
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RWU RM-4452 Effects of Atmospheric Change on Alpine and Subalpine Ecosystems
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RWU INT-4401-Fire Behavior: Fundamentals and Systems Development
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RWU NE-4558 Impact of Atmospheric Deposition and Global Change on Forest Health and Productivity
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RWU NE-4454-Integrating the Ecological and Social Dimensions of Forest Ecosystem Management

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